PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

PCT

To:
WITHERS & ROGERS
Attn. CHETTLE, Adrian John
Goldings House
2 Hays Lane
London SE1 2HW
UNITED KINGDOM

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT OR THE DECLARATION

(PCT Rule 44.1)

	Date of mailing *(day/month/year)* 24/11/2000
Applicant's or agent's file reference P700600PCT/JG/SAC	**FOR FURTHER ACTION** See paragraphs 1 and 4 below
International application No. PCT/GB 00/02920	International filing date *(day/month/year)* 28/07/2000
Applicant INTERNATIONAL ALUMINIUM HOLDINGS LIMITED et al.	

1. [X] The applicant is hereby notified that the International Search Report has been established and is transmitted herewith.

Filing of amendments and statement under Article 19:
The applicant is entitled, if he so wishes, to amend the claims of the International Application (see Rule 46):

When? The time limit for filing such amendments is normally 2 months from the date of transmittal of the International Search Report; however, for more details, see the notes on the accompanying sheet.

Where? Directly to the International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland
Fascimile No.: (41-22) 740.14.35

For more detailed instructions, see the notes on the accompanying sheet.

2. [ ] The applicant is hereby notified that no International Search Report will be established and that the declaration under Article 17(2)(a) to that effect is transmitted herewith.

3. [ ] **With regard to the protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:

[ ] the protest together with the decision thereon has been transmitted to the International Bureau together with the applicant's request to forward the texts of both the protest and the decision thereon to the designated Offices.

[ ] no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Further action(s):** The applicant is reminded of the following:

Shortly after **18 months** from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau as provided in Rules 90*bis*.1 and 90*bis*.3, respectively, before the completion of the technical preparations for international publication.

Within **19 months** from the priority date, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase until 30 months from the priority date (in some Offices even later).

Within **20 months** from the priority date, the applicant must perform the prescribed acts for entry into the national phase before all designated Offices which have not been elected in the demand or in a later election within 19 months from the priority date or could not be elected because they are not bound by Chapter II.

Name and mailing address of the International Searching Authority	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Paul Faux

Form PCT/ISA/220 (July 1998)

NOTES TO FORM PCT/ISA/220

These Notes are intended to give the basic instructions concerning the filing of amendments under article 19. The Notes are based on the requirements of the Patent Cooperation Treaty, the Regulations and the Administrative Instructions under that Treaty. In case of discrepancy between these Notes and those requirements, the latter are applicable. For more detailed information, see also the PCT Applicant's Guide, a publication of WIPO.

In these Notes, "Article", "Rule", and "Section" refer to the provisions of the PCT, the PCT Regulations and the PCT Administrative Instructions respectively.

INSTRUCTIONS CONCERNING AMENDMENTS UNDER ARTICLE 19

The applicant has, after having received the international search report, one opportunity to amend the claims of the international application. It should however be emphasized that, since all parts of the international application (claims, description and drawings) may be amended during the international preliminary examination procedure, there is usually no need to file amendments of the claims under Article 19 except where, e.g. the applicant wants the latter to be published for the purposes of provisional protection or has another reason for amending the claims before international pbulication. Furthermore, it should be emphasized that provisional protection is available in some States only.

What parts of the International application may be amended?

Under Article 19, only the claims may be amended.

During the international phase, the claims may also be amended (or further amended) under Article 34 before the International Preliminary Examining Authority. The description and drawings may only be amended under Article 34 before the International Examining Authority.

Upon entry into the national phase, all parts of the international application may be amended under Article 28 or, where applicable, Article 41.

When?

Within 2 months from the date of transmittal of the international search report or 16 months from the priority date, whichever time limit expires later. It should be noted, however, that the amendments will be considered as having been received on time if they are received by the International Bureau after the expiration of the applicable time limit but before the completion of the technical preparations for international publication (Rule 46.1).

Where not to file the amendments?

The amendments may only be filed with the International Bureau and not with the receiving Office or the International Searching Authority (Rule 46.2).

Where a demand for international preliminary examination has been/is filed, see below.

How?

Either by cancelling one or more entire claims, by adding one or more new claims or by amending the text of one or more of the claims as filed.

A replacement sheet must be submitted for each sheet of the claims which, on account of an amendment or amendments, differs from the sheet originally filed.

All the claims appearing on a replacement sheet must be numbered in Arabic numerals. Where a claim is cancelled, no renumbering of the other claims is required. In all cases where claims are renumbered, they must be renumbered consecutively (Administrative Instructions, Section 205(b)).

The amendments must be made in the language in which the international application is to be published.

What documents must/may accompany the amendments?

Letter (Section 205(b)):

The amendments must be submitted with a letter.

The letter will not be published with the international application and the amended claims. It should not be confused with the "Statement under Article 19(1)" (see below, under "Statement under Article 19(1)").

The letter must be in English or French, at the choice of the applicant. However, if the language of the international application is English, the letter must be in English; if the language of the international application is French, the letter must be in French.

The letter must indicate the differences between the claims as filed and the claims as amended. It must, in particular, indicate, in connection with each claim appearing in the international application (it being understood that identical indications concerning several claims may be grouped),whether

(i) the claim is unchanged;

(ii) the claim is cancelled;

(iii) the claim is new;

(iv) the claim replaces one or more claims as filed;

(v) the claim is the result of the division of a claim as filed.

The following examples illustrate the manner in which amendments must be explained in the accompanying letter:

1. [Where originally there were 48 claims and after amendment of some claims there are 51]:
"Claims 1 to 29, 31, 32, 34, 35, 37 to 48 replaced by amended claims bearing the same numbers; claims 30, 33 and 36 unchanged; new claims 49 to 51 added."

2. [Where originally there were 15 claims and after amendment of all claims there are 11]:
"Claims 1 to 15 replaced by amended claims 1 to 11."

3. [Where originally there were 14 claims and the amendments consist in cancelling some claims and in adding new claims]:
"Claims 1 to 6 and 14 unchanged; claims 7 to 13 cancelled; new claims 15, 16 and 17 added." or
"Claims 7 to 13 cancelled; new claims 15, 16 and 17 added; all other claims unchanged."

4. [Where various kinds of amendments are made]:
"Claims 1-10 unchanged; claims 11 to 13, 18 and 19 cancelled; claims 14, 15 and 16 replaced by amended claim 14; claim 17 subdivided into amended claims 15, 16 and 17; new claims 20 and 21 added."

"Statement under article 19(1)" (Rule 46.4)

The amendments may be accompanied by a statement explaining the amendments and indicating any impact that such amendments might have on the description and the drawings (which cannot be amended under Article 19(1)).

The statement will be published with the international application and the amended claims.

It must be in the language in which the international appplication is to be published.

It must be brief, not exceeding 500 words if in English or if translated into English.

It should not be confused with and does not replace the letter indicating the differences between the claims as filed and as amended. It must be filed on a separate sheet and must be identified as such by a heading, preferably by using the words "Statement under Article 19(1)."

It may not contain any disparaging comments on the international search report or the relevance of citations contained in that report. Reference to citations, relevant to a given claim, contained in the international search report may be made only in connection with an amendment of that claim.

Consequence if a demand for international preliminary examination has already been filed

If, at the time of filing any amendments under Article 19, a demand for international preliminary examination has already been submitted, the applicant must preferably, at the same time of filing the amendments with the International Bureau, also file a copy of such amendments with the International Preliminary Examining Authority (see Rule 62.2(a), first sentence).

Consequence with regard to translation of the international application for entry into the national phase

The applicant's attention is drawn to the fact that, where upon entry into the national phase, a translation of the claims as amended under Article 19 may have to be furnished to the designated/elected Offices, instead of, or in addition to, the translation of the claims as filed.

For further details on the requirements of each designated/elected Office, see Volume II of the PCT Applicant's Guide.

PATENT COOPERATION TREATY

From the
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

To:

CHETTLE, Adrian John
WITHERS & ROGERS
Goldings House
2 Hays Lane
London SE1 2HW
GRANDE BRETAGNE

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Rule 71.1)

Date of mailing *(day/month/year)*	12.11.2001
Applicant's or agent's file reference: P700600PCT/JG/SAC	**IMPORTANT NOTIFICATION**

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/GB00/02920	28/07/2000	06/08/1999

Applicant
INTERNATIONAL ALUMINIUM HOLDINGS LIMITED et al.

1. The applicant is hereby notified that this International Preliminary Examining Authority transmits herewith the international preliminary examination report and its annexes, if any, established on the international application.

2. A copy of the report and its annexes, if any, is being transmitted to the International Bureau for communication to all the elected Offices.

3. Where required by any of the elected Offices, the International Bureau will prepare an English translation of the report (but not of any annexes) and will transmit such translation to those Offices.

4. **REMINDER**

The applicant must enter the national phase before each elected Office by performing certain acts (filing translations and paying national fees) within 30 months from the priority date (or later in some Offices) (Article 39(1)) (see also the reminder sent by the International Bureau with Form PCT/IB/301).

Where a translation of the international application must be furnished to an elected Office, that translation must contain a translation of any annexes to the international preliminary examination report. It is the applicant's responsibility to prepare and furnish such translation directly to each elected Office concerned.

For further details on the applicable time limits and requirements of the elected Offices, see Volume II of the PCT Applicant's Guide.

Name and mailing address of the IPEA/	Authorized officer
European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Schacht, I Tel.+49 89 2399-2381

Form PCT/IPEA/416 (July 1992)

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
P700600PCT/JG/SAC		
International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/GB00/02920	28/07/2000	06/08/1999

International Patent Classification (IPC) or national classification and IPC
B23K9/23

Applicant
INTERNATIONAL ALUMINIUM HOLDINGS LIMITED et al.

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 7 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 5 sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   - VI ☐ Certain documents cited
   - VII ☒ Certain defects in the international application
   - VIII ☒ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
28/02/2001	12.11.2001

Name and mailing address of the international preliminary examining authority:

European Patent Office
D-80298 Munich
Tel. +49 89 2399 - 0 Tx: 523656 epmu d
Fax: +49 89 2399 - 4465

Authorized officer

Caubet, J-S

Telephone No. +49 89 2399 2344

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/GB00/02920

I. Basis of the report

1. With regard to the **elements** of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17))*:
Description, pages:

1-9	as originally filed			
Claims, No.:				
1-21,32-48	filed with the demand			
22-31	as received on	11/07/2001	with letter of	09/07/2001
Drawings, sheets:				
1/4-4/4	as originally filed			

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

   These elements were available or furnished to this Authority in the following language: , which is:

   - ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
   - ☐ the language of publication of the international application (under Rule 48.3(b)).
   - ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

   - ☐ contained in the international application in written form.
   - ☐ filed together with the international application in computer readable form.
   - ☐ furnished subsequently to this Authority in written form.
   - ☐ furnished subsequently to this Authority in computer readable form.
   - ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   - ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

- ☐ the description, pages:
- ☐ the claims, Nos.:
- ☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

   (Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-25,27,33-48
	No:	Claims	26,28-32
Inventive step (IS)	Yes:	Claims	1-24,33-35
	No:	Claims	26-32,36-48
Industrial applicability (IA)	Yes:	Claims	1-48
	No:	Claims	

2. Citations and explanations
   see separate sheet

VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:
see separate sheet

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:
see separate sheet

Re Item V

Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1) Reference is made to the following documents:

D1: DE-A-35 35 212
D2: US-A-4 159 410
D3: JP-A-60 0015070
D4: WO-A-99-03634
D5: JP-A-59 212169
D6: US-A-5 449 107

2) The document D1 shows:

A welding apparatus (suitable for welding two or more overlapping members having a tenacious surface oxide layer), comprising a plasma arc torch (PD) operable to form a weld pool in a work piece, and weld pool disturbing means (Z) comprising a disturbing member which is movable, in use (by changing the wire feed speed for example), into the weld pool to a depth sufficient to penetrate overlapping oxide layers present in the weld pool.

These features are known from D2 (see abstract and figures) as well.

The subject-matter of claim 26 is therefore not novel (Article 33(2) PCT).

From a general point of view, it is noted that the features of claim 26 do not allow the differentiation between a "weld pool disturbing means", especially designed for performing the method of claim 1, and a common weld wire feed mechanism, as shown in D1 and D2.

3) The features of claims 28-32 are known from D1 and D2 as well.

The features of claims 27, 36, 37, 39, 40 are known from D3. Document D5 shows the features of claims 27, 36, 41, 42, 45, and D6 those from claims 43 and 44. Claims 38 and 46-48 only disclose obvious possibilities.

Therefore dependent claims 27-32, 36-48 do not contain any features which, in combination with the features of any claim to which they refer, meet the requirements of the PCT in respect of novelty or inventive step.

4) To claim 1:

Document D4, which is considered to represent the most relevant state of the art, discloses:

> A method of welding two or more overlapping members having a tenacious surface oxide layer comprising melting said members at a predetermined location to form a weld pool;

from which the subject-matter of claim 1 differs by disturbing the weld pool by introducing a disturbing member into the weld pool.

The subject-matter of claim 1 is therefore novel (Article 33(2) PCT).

The problem to be solved by the present invention may therefore be regarded as providing an alternative method for welding overlapping members without removing an oxide layer.

The solution to this problem proposed in claim 1 of the present application is considered as involving an inventive step (Article 33(3) PCT) for the following reasons:

> D4 discloses a resistance welding process; this means that the melt area is located between the overlapping members. For this reason D4 cannot give any indication that a disturbing member may be entered into the melt pool to enable mixing of the molten metal. No available document shows the

introduction of a disturbing member into the melt pool in a process of welding overlapping members having a layer of tenacious oxide.

5) Claims 2-25 are dependent on claim 1 and as such also meet the requirements of the PCT with respect to novelty and inventive step.

6) The combination of the features of dependent claim 33 is neither known from, nor rendered obvious by, the available prior art. These features allow the performance of the method according to claim 1 and therefore solve the above mentioned problem. It is noted that a non-consumable disturbing member is not comparable with a weld wire, which is consumable by definition.

Re Item VII

Certain defects in the international application

7) Independent claims 1 and 26 are not in the two-part form in accordance with Rule 6.3(b) PCT, which in the present case would be appropriate, with those features known in combination from the prior art (document D4 for claim 1; D1 for claim 26) being placed in the preamble (Rule 6.3(b)(i) PCT) and with the remaining features being included in the characterising part (Rule 6.3(b)(ii) PCT).

8) The features of the claims are not provided with reference signs placed in parentheses (Rule 6.2(b) PCT).

9) Contrary to the requirements of Rule 5.1(a)(ii) PCT, the relevant background art disclosed in the documents D1 and D4 is not mentioned in the description, nor are these documents identified therein.

Re Item VIII

Certain observations on the international application

10) Claim 26 broadly defines the feature of the weld pool disturbing means in terms of its function, which is to move into the weld pool and penetrate oxide layers. This functional statement however does not enable the skilled person to determine which technical features are necessary to perform the stated function. Claim 26 therefore does not meet the requirements of Article 6 PCT in that the matter for which protection is sought is not clearly defined.

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

CORRECTED VERSION

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
15 February 2001 (15.02.2001)

PCT

(10) International Publication Number
WO 01/10592 A1

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(21) International Application Number: PCT/GB00/02920

(22) International Filing Date: 28 July 2000 (28.07.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
9918476.4 6 August 1999 (06.08.1999) GB
9924304.0 15 October 1999 (15.10.1999) GB

(71) Applicant *(for all designated States except US)*: INTERNATIONAL ALUMINIUM HOLDINGS LIMITED [GB/GB]; Unit 2, Parbrook Close, Torrington Avenue, Coventry CV4 9XY (GB).

(72) Inventor; and
(75) Inventor/Applicant *(for US only)*: HUGHES, Russell, Vernon [GB/GB]; 22 Shakleton Road, Earlsdon, Coventry CV5 6HU (GB).

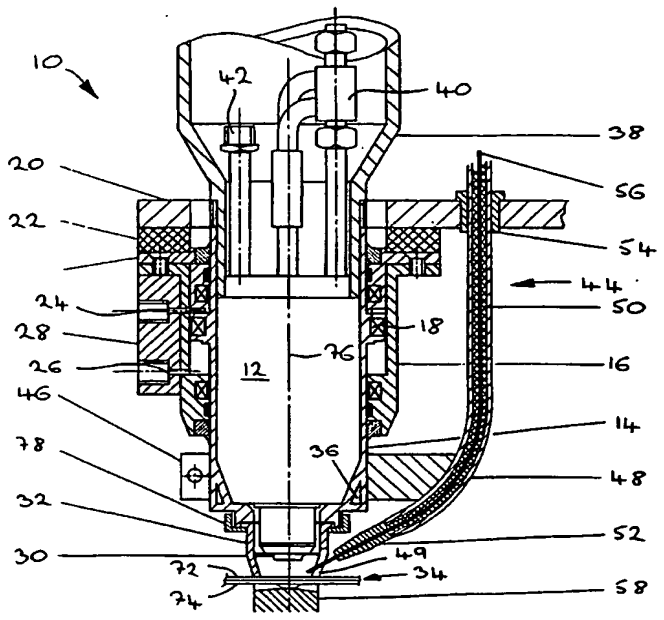
(74) Agents: CHETTLE, Adrian, John et al.; Withers & Rogers, Goldings House, 2 Hays Lane, London SE1 2HW (GB).

(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

[Continued on next page]

(54) Title: WELDING APPARATUS AND METHOD



(57) Abstract: A welding apparatus (10) for welding two or more overlapping members (72, 74) having a tenacious surface oxide layer, the apparatus (10) comprising a plasma arc torch (12) operable to form a weld pool (80) in a work piece (34), and weld pool disturbing means operable, in use, to disturb a weld pool (80) formed by the plasma arc torch (12), the weld pool disturbing means comprising a disturbing member (56) which is movable into the weld pool (80). The apparatus (10) may include a support member (58) adapted to support the weld pool (80).

WO 01/10592 A1

WO 01/10592 A1

Published:
— *With international search report.*
— *With amended claims.*

(48) Date of publication of this corrected version:
3 May 2001

(15) Information about Correction:
see PCT Gazette No. 18/2001 of 3 May 2001, Section II

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

1. A method of welding two or more overlapping members having a tenacious surface oxide layer, the method comprising the steps of:

melting said members at a predetermined location to form a weld pool; and

disturbing the weld pool by introducing a disturbing member into the weld pool.

2. A method as claimed in claim 1, wherein the step of melting the members to form the weld pool is achieved by a using a plasma arc torch.

3. A method as claimed in claim 1 or claim 2, and including the step of clamping the overlapping members prior to forming the weld pool.

4. A method as claimed in any preceding claim, wherein the disturbing member is consumable.

5. A method as claimed in claim 4, wherein the disturbing member has a composition the same or similar to that of the metal forming the two or more members.

6. A method as claimed in any preceding claim, wherein the step of disturbing the weld pool comprises the steps of advancing the disturbing member into the weld pool at a predetermined rate and to a predetermined depth, and then withdrawing the disturbing member at a predetermined rate.

7. A method as claimed in claim 6, and including the intermediate step of holding the disturbing member in the weld pool for a predetermined time.

8. A method as claimed in claim 6 or claim 7, wherein the speed of advance and withdrawal of the disturbing member is variable.

9. A method as claimed in claim 8, wherein, the speed of withdrawal is equal to or faster than the speed of advance.

10. A method as claimed in any of claims 1 to 3, wherein the disturbing member is non-consumable.

11. A method as claimed in claim 10, wherein the disturbing member is made from a material which is not wetted by the molten metal of the weld pool.

12. A method as claimed in claim 10 or 11, wherein the step of disturbing the weld pool comprises the steps of advancing the disturbing member into the weld pool at a predetermined rate and to a predetermined depth, and then withdrawing the disturbing member.

13. A method as claimed in claim 12, and including the intermediate step of holding the disturbing member in the weld pool for a predetermined time.

14. A method as claimed in any preceding claim, wherein the movement of the disturbing member is at a relatively shallow angle to the plane of the weld.

15. A method as claimed in claim 14, wherein the angle is above 30°.

16. A method as claimed in claim 14 or claim 15, wherein the angle is up to 45°.

17. A method as claimed in any preceding claim, wherein the disturbing member is introduced into the weld pool to one side thereof to promote a stirring effect.

18. A method as claimed in claim 17, wherein two or more disturbing members are provided to promote such stirring.

19. A method as claimed in any preceding claim, the method including disturbance of the weld pool by a welding gas.

20. A method as claimed in claim 19 when dependant upon claim 2, the method including disturbance of the weld pool by the action of a shielding gas.

21. A method as claimed in claim 19 when dependent upon claim 2, or claim 20, the method including disturbance of the weld pool by the action of a plasma gas.

22. A method as claimed in any of claims 19 to 21, wherein the gas is caused to impinge on the weld pool at an angle and in a manner so as to promote swirling of the weld pool.

23. A method as claimed in any of claims 19 to 22, wherein the gas has a rotational component achieved by rifling in a gas delivery jet or nozzle.

24. A method as claimed in any preceding claim, wherein the weld pool is supported from beneath.

25. A method as claimed in claim 2, wherein the step of disturbing the weld pool includes disturbance by pulsing a welding current of a plasma arc torch.

26. A welding apparatus for welding two or more overlapping members having a tenacious surface oxide layer, the apparatus comprising a plasma arc torch operable to form a weld pool in a work piece, and weld pool disturbing means comprising a disturbing member which is movable into the weld pool to a depth sufficient to penetrate overlapping oxide layers present in the weld pool.

27. An apparatus as claimed in claim 26, and including a weld pool supporting member.

28. An apparatus as claimed in claim 26 or claim 27, wherein the disturbing member is consumable

29. An apparatus as claimed in claim 28 wherein the disturbing member comprises a wire or filament having a composition the same or similar to that of the workpiece.

30. An apparatus as claimed in claim 29, wherein the wire or filament is movable by a feed mechanism.

31. An apparatus as claimed in claim 30, wherein the feed mechanism is operable to move the wire or filament at one or more predetermined feed rates relative to the weld pool, in use.

32. An apparatus as claimed in claim 30 or claim 31, wherein the feed mechanism includes guide means to guide the wire or filament to a predetermined location in the weld pool.

33. An apparatus as claimed in claim 26 or claim 27, wherein the disturbing member is non-consumable.

34. An apparatus as claimed in claim 33 wherein the disturbing member comprises a lance or like implement.

35. An apparatus as claimed in claim 34, wherein the disturbing member is made from a material which is not wetted by the molten metal of the weld pool.

36. An apparatus as claimed in claim 27, wherein the support member comprises a support surface having a recess adapted to support the weld pool.

37. An apparatus as claimed in claim 36, wherein the support member is adapted to allow the recess to vent when the weld pool is formed.

38. An apparatus as claimed in claim 36 or 37, wherein the support surface is provided with one or more open channels extending from the recess.

39. An apparatus as claimed in any of claims 36 to 38, the support member comprising a body having an insert, the insert defining the support surface, wherein the insert is manufactured from a material having a lower thermal conductivity than the material of the body.

40. An apparatus as claimed in claim 39 wherein the insert is a ceramic material

41. An apparatus as claimed clim 39 wherein the insert is electrically conductive.

42. An apparatus as claimed in claim 41 wherein the insert is a graphite based material.

43. An apparatus as claimed in any of claims 36 to 42, wherein the support member is provided with a cooling system.

44. An apparatus as claimed in claim 43, wherein the support member has a substantially hollow interior through which coolant is circulatable.

45. An apparatus as claimed in any of claims 36 to 38, wherein the support member has a peripheral raised edge against which the work piece is received.

46. An apparatus as claimed in claim 45, wherein the edge is discontinuous.

47. An apparatus as claimed in any of claims 26 to 46, wherein the plasma arc torch and supporting member are movable relative to one another so as to enable the work piece to be clamped therebetween.

48. An apparatus as claimed in any of claims 26 to 47, wherein an electric welding current of the plasma torch is pulsable during welding in order to assist disturbance of the oxide layer

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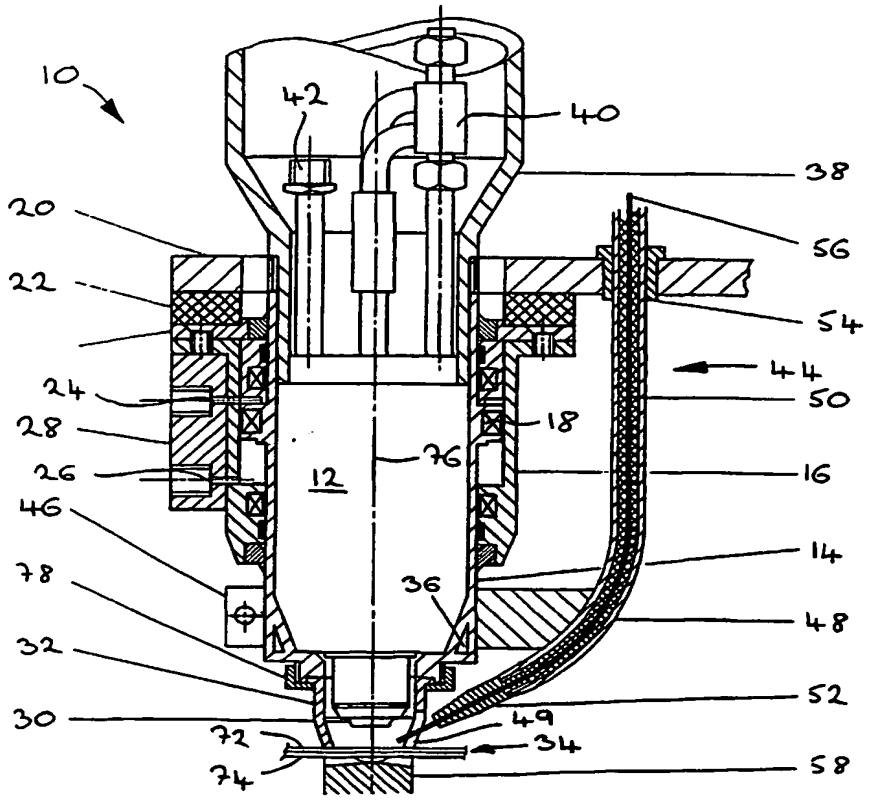
(54) Title: WELDING APPARATUS AND METHOD



(57) Abstract: A welding apparatus (10) for welding two or more overlapping members (72, 74) having a tenacious surface oxide layer, the apparatus (10) comprising a plasma arc torch (12) operable to form a weld pool (80) in a work piece (34), and weld pool disturbing means operable, in use, to disturb a weld pool (80) formed by the plasma arc torch (12), the weld pool disturbing means comprising a disturbing member (56) which is movable into the weld pool (80). The apparatus (10) may include a support member (58) adapted to support the weld pool (80).

WO 01/10592 A1

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Welding Apparatus and Method

The present invention relates to welding and in particular to welding metals having a surface oxide layer such as, for example, aluminium alloy.

The high strength and low weight of aluminium alloy has traditionally lead to its use in areas where such factors are critical, for example in the aerospace industry. More recently it has begun to be used in the automotive industry as the material for vehicle bodies.

Difficulties exist in the welding of aluminium alloy due to its inherent nature. The high thermal conductivity of aluminium alloy ranges from three to five times that of steel, with the result that significantly higher inputs of energy are required to achieve fusion. For the welding of thick sections preheating of the work pieces may be necessary. Aluminium and its alloys have a surface film of aluminium oxide which forms rapidly when the aluminium is exposed to the atmosphere. It has been necessary to remove this oxide layer before welding as it prevents fusion between the work pieces. Oxide removal operations are time consuming and require a high degree of work piece cleanliness to be maintained if subsequent welding operations are to be successful. Magnesium and its alloys are also beginning to be considered for automotive applications. Like aluminium, magnesium also forms a surface oxide layer when exposed to the atmosphere.

These inherent problems with welding aluminium, magnesium and their alloys have thus far restricted their use in the automotive industry to top of the range vehicles and have necessitated the use of less desirable alternative joining methods such as riveting and adhesives.

According to a first aspect of the present invention there is provided a method of welding two or more overlapping members having a tenacious surface oxide layer, the method comprising the steps of:

melting said members at a predetermined location to form a weld pool; and

disturbing the weld pool.

The step of disturbing of the weld pool enables sufficient mixing of the molten metal of the work pieces to ensure fusion therebetween. In particular, the step of disturbing the weld pool serves to break down any layer of oxide in the weld pool which, if left undisturbed, would prevent fusion.

In a preferred embodiment the step of melting the members to form the weld pool is achieved by a using a plasma arc torch. The method may include the step of clamping the overlapping members prior to forming the weld pool.

Disturbance of the weld pool may be achieved by introducing a disturbing member into the weld pool. In one embodiment the disturbing member may be consumable, for example a wire having a composition the same or similar to that of the metal forming the two or more members. In such an embodiment, the step of disturbing the weld pool may comprise the steps of advancing the disturbing member into the weld pool at a predetermined rate and to a predetermined depth, and then withdrawing the disturbing member at a predetermined rate. The method may include the intermediate step of holding the disturbing member in the weld pool for a predetermined time.

Preferably the speed of advance and withdrawal of the disturbing member is variable, and in a preferred embodiment the speed of withdrawal is equal to or faster than the speed of advance.

In an alternative embodiment the disturbing member may be non-consumable, for example a lance made from a material which is not wetted by the molten metal of the weld pool. The lance may be made from, for example platinum or a ceramic material. In such an alternative embodiment, the step of disturbing the weld pool may comprise the steps of advancing the lance into the weld pool at a predetermined rate and to a predetermined depth, and then withdrawing the lance. Again, the method may include the intermediate steps of holding the lance in the weld pool for a predetermined time.

Disturbance of the weld pool may be caused or promoted by the action of the plasma gas and/or the shielding gas. The gas may for example impinge on the weld pool at an angle in a manner so as to promote swirling. The plasma and/or shield gas may itself have a rotational component, for example introduced by rifling in a gas delivery jet.

The weld pool is preferably supported from beneath to avoid slumping. Such an arrangement is desirable in the case of single sided spot welding and has the additional advantage of providing control over the shape and appearance of the solidified weld. It will however be understood that welding according to the method described herein This latter aspect may be an important consideration in cases where the cosmetic appearance of the weld is important, or where a smooth surface finish is desirable.

In an alternative embodiment the support may be provided with a recess within which, in use, the weld pool is supported. The use of such a recess results in the face of the workpiece which rests there against during welding being provided with raised projections corresponding to the shape of the recess. In a run of multiple welds, the aforementioned face of the workpiece is thus provided with a repeated run of substantially identical projections. The recess may be configured so as to provide a aesthetically pleasing projection, for example a smooth dome. In an alternative embodiment the recess may be configured so as to provide a projection which is later utilisable to locate or align a component with respect to the workpiece.

If however, the weld is performed in carefully controlled conditions, a support may not be necessary. Precise regulation of the plasma gas and welding current can melt an upper layer of material whilst merely heating the lower layer. In this case the oxide layer may insulate the lower layer somewhat. As the weld pool of the upper layer is disturbed, the oxide layer is sufficiently disrupted to permit momentary melting of the lower layer, and formation of a unitary weld pool. Immediate reduction of current, plasma gas flow and/or cooling causes the weld to solidify without slumping.

In a preferred embodiment, the movement of the disturbing member is at a relatively shallow angle to the plane of the weld, preferably above 30° and most preferably up to 45°.

The disturbing member is preferably introduced into the weld pool to one side thereof, thus promoting a stirring effect which more effectively promotes mixing in the weld pool. Two or more disturbing members may be provided to promote such stirring.

In a preferred embodiment a single sided spot weld between two strips of 5754 aluminium alloy required a plasma gas (Argon) flow rate of 1.5-1.8 litre per minute, and a disturbing member comprising a single filler wire of 5554 aluminium alloy and a diameter of 1.6 mm. Such a weld had a smooth appearance with an approximate overall diameter of 8 mm on the blind side and 10 mm on the front side. Needless to say, a thinner wire would require a faster rate of feed and be more likely to buckle. A thicker wire might be more difficult to feed to the weld pool because of curvature of the feed path. Typically, in the above example, a feed speed of 4m/min. and a withdrawal speed of 5m/min. are suitable. These factors are variable by the skilled man in order to obtain a optimum weld.

In the case of a supported weld pool, the oxide layer may be broken or disrupted by slumping the weld pool into a support recess of appropriate size. The oxide layer has no resilience, and consequently no resistance to deformation. Mixing may be promoted, by for example a swirling effect introduced by the plasma and/or shielding gas.

Pulsing of a welding current may also disturb the weld pool, for example by stepping an A.C. current up and down.

According to a second aspect of the present invention there is provided a welding apparatus comprising a plasma arc torch operable to form a weld pool in a work piece, and weld pool disturbing means operable, in use, to disturb a weld pool formed by the plasma arc torch. Optionally a weld pool supporting member may be provided.

The weld pool disturbing means preferably comprise a disturbing member which is movable into the weld pool. In one embodiment the disturbing member may be consumable, and comprise a wire or filament having a composition the same or similar to that of the workpiece. In such an embodiment the wire or filament may be movable by a feed mechanism. The feed mechanism may be operable to move the wire or filament at one or more predetermined feed rates relative to the weld pool, in use. Preferably the feed mechanism includes guide means to guide the wire or filament to a predetermined location in the weld pool. In an alternative embodiment the disturbing means may be non-consumable, and comprise a lance or like implement. The lance is preferably be made from a

material which is not wetted by the molten metal of the weld pool. More than one wire, filament or lance may be provided.

The support member comprises a support surface having a recess adapted to support the weld pool. In a preferred embodiment the support member is adapted to allow the recess to vent when the weld pool is formed. The support surface may be provided with one or more open channels extending from the recess. Preferably the support member is provided with a cooling system. The support member may have a substantially hollow interior through which coolant can be circulated.

The support member may have a peripheral raised edge against which the work piece is received. Such an edge, which may be discontinuous, reduces conduction of heat from the work piece to the support, and allows a relatively easily adjustable means of varying the heat transfer characteristics of the weld. The raising of the edge may be very small, and in the order of 0.05mm.

In an alternative embodiment the support member may comprise a body having an insert, the insert defining the support surface, wherein the insert is manufactured from a material having a lower thermal conductivity than the material of the body. The use of such an insert reduces the amount of heat energy transferred to the support during welding and hence reduces the energy input required from the plasma torch. The insert may be manufactured from a ceramics material, for example reaction bonded silicon nitride. Alternatively the insert may be manufactured from an electrically conductive material, for example a graphite based material.

The plasma arc torch and support member may be movable relative to one another so as to enable the work piece to be clamped therebetween.

In a preferred embodiment, an electric welding current may be pulsed during welding in order to disturb the oxide layer and/or to regulate the heat input to the weld. Such an arrangement may be especially useful in avoiding slumping of non-horizontal welds.

An embodiment of the present invention will now be described with reference to the accompanying drawings in which:

Figure 1 shows cross-sectional side view of a welding apparatus in accordance with the present invention;

Figures 2a to 2c show diagrammatic side view of a welding operation according to the present invention;

Figure 3 shows a perspective view of a support member according to the present invention;

Figure 4 shows a cross-sectional side view of a first alternative support member; and

Figure 5 shows a cross-sectional side view of a second alternative support member.

Referring firstly to figure 1 there is shown a welding apparatus, generally designated 10, adapted to produce spot welds. The welding apparatus comprises a plasma arc welding torch 12 mounted on a movable carriage 14. The carriage 14 is movable within a cylinder 16, and an outer portion of the carriage 14 carries a peripheral seal 18 which enables the carriage 14 to act as a piston. The cylinder 16 is connected to a mounting bracket 20 via a vibration absorbent compliance ring 22. The carriage 14 is movable relative to the cylinder 16 by the selective application of fluidic pressure, for example pneumatic pressure, to the cylinder 16 via apertures 24,26 provided in the wall thereof. As can be readily seen, the apertures 24,26 are provided above and below the peripheral seal 18. A porting block 28 is provided adjacent the apertures 24,26 to enable connection of a suitable source of fluidic pressure.

The constricting orifice 30 of the plasma torch 12 projects from the carriage 14 and is shrouded by a clamp cup 32 carried by the carriage 14. The clamp cup 32 is connected to the carriage 14 by a retaining ring 78. The clamp cup 30 serves, in use, both to clamp a work piece 34 and to ensure adequate gas shielding of the weld site. Both functions of the clamp cup 32 will be described in more detail below. The carriage 14 is provided with cooling channels 36 to allow the circulation of coolant to cool the plasma torch 12 when it is in operation. The plasma torch 12 is retained in the carriage 14 by a tubular retaining sheath 38. The sheath 38 also houses the gas and power connections 40,42 of the plasma torch 12

A filler wire guide, generally designated 44, is connected to the carriage 14 by a support clamp 46. The wire guide 44 comprises a curved guide tube 48 containing a liner 50, and a tapered tip 52. In the embodiment shown the guide

tube 48 passes through the mounting bracket 20. As guide tube 48 is connected to the movable carriage 14 by the support clamp 46, an insulated guide bush 54 is provided in the mounting bracket 20 to allow relative movement of the guide tube 48. Filler wire 56 is movable through the wire guide 44 by an appropriate feed mechanism (not shown). Typically the filler wire is stored in the feed mechanism on a drum. The tip 52 of wire guide 44 is positioned so as to, in use, feed the filler wire 56 through an aperture 49 in the clamp cup 32.

A support member 58 is shown in figure 1 and also in greater detail in figure 3. The support member 58 has a support surface 60 against which the work piece 34 rests in use. The support member 58 has a substantially hollow interior into which coolant can be circulated via an inlet 62 and an outlet 63. A recess 64 is provided in the support surface 60 and two channels 66,68 extend in opposite directions from the recess 64 to the edge 70 of the support surface 60.

Operation of the welding apparatus 10 will now be described with reference to all of the figures. In the embodiment shown the workpiece 34 comprises two overlapping sheets 72,74 of aluminium alloy. The sheets 72,74 are positioned such that the intended position of the weld is aligned with a nominal axis 76 passing through the plasma torch 12 and the recess 64 in the support member 58 as shown in figure 1. The carriage 14 is lowered until the clamp cup 32 abuts the work piece 34, and the work piece 34 is clamped against the support member 58. This clamping action reduces the possibility of the sheets 72,74 moving relative to one another during the subsequent welding operation.

The welding torch 12 is then operated to produce localised melting of the work piece 34 to form a weld pool 80. The weld pool 80 is contained by the recess 64 of the support member 58 as shown in figure 2b. As the weld pool 80 forms, air present in the recess 64, which expands due to the heating of the work piece 34, vents via the channels 66,68. Without the channels 66,68, the only means of escape for the expanding air would be through the molten weld pool 80 which could result in the weld pool 80 being blown from the recess 64. The channels 66,68 also provide a means of escape for surface coatings present on the lower surface of the workpiece 34, which coatings liquefy as a result of the formation of the weld pool 80. For example the work piece 34 may be provided with a protective surface coating of wax.

Once the weld pool 80 has formed, there remain thin layers of aluminium oxide, shown by broken lines 82 in figure 2b, between the molten metal of the respective sheets 72,74. These oxide layers 82 comprises the oxide present on the facing surfaces of each sheet 72,74. This prevents the mixing of the molten metal of the sheets 72,74, and hence prevents fusion. To overcome this, filler wire 56 is advanced into the weld pool 80 to disturb the oxide layers 82 as shown in figure 2c. Once the oxide layers 82 are penetrated by the filler wire 56, convective forces within the weld pool 80 ensure sufficient mixing of the molten sheet metal to achieve fusion. The filler wire 56 typically has a composition which is the same as that of the alloy sheets 72,74, for example a mixture of aluminium and magnesium or silicon. Once the filler wire 56 has been advanced into the weld pool 80, it is held there for a predetermined time to allow a portion thereof to melt and become incorporated in the weld. After said predetermined time has elapsed the filler wire 56 is retracted. The work piece 34 can then be unclamped and removed from the apparatus 10.

Figure 4 shows an alternative support member 58 having a peripheral raised edge 84 which defines a substantially annular support surface 60.

The recess 64 within which the weld pool is supported in use, is provided in the middle of the annular support surface 60. In use, the raised edge 84 enables an air gap 86 to be provided between the support member 58 and the workpiece 34 in the vicinity of the weld site. The air gap 86 reduces the transfer of heat from the workpiece 34 to the support member 58 during welding.

Figure 5 shows a further support member 58 having an insert 88 therein. The insert 88 is configured so as to define the above described recess 64 and vent channels 66. The insert is manufactured from a material having a lower thermal conductivity than that of the main body of the support member 58. The insert may be a high temperature non-metallic material which, in use, is not wetted by the molten metal of the weld pool. The insert may be a ceramic material such as, for example, reaction bonded silicon nitride.

The use of an insert of a material having a lower thermal conductivity advantageously may eliminate the need for the support member 58 to be cooled as less heat energy is transferred thereto during welding It will be appreciated that heat energy transferred to the support 58 is, in effect, wasted as it is not used in the heating of the workpiece and the formation of the weld pool. Thus by

reducing the energy transfer to the support 58 there is a consequential reduction in the energy needed to achieve a weld. Taking the example of welding two overlapping aluminium alloy sheets each having a thickness of 1 mm and utilising a water cooled copper support has been observed to require a welding current of around 150 amps for a duration of about 3 seconds. In contrast, by substituting an uncooled copper support having a ceramic insert a similar weld could be achieved using a welding current of around 105 amps for a duration of about 2 seconds.

Alternatively the insert may be manufactured from an electrically conductive material having a lower thermal conductivity than the main body of the support 58. Such an insert ensures that the support in its entirety is electrically conductive and thus eliminates the possibility that the electrical circuit formed, in use, between the workpiece and the plasma torch may be broken during welding.

Claims

1. A method of welding two or more overlapping members having a tenacious surface oxide layer, the method comprising the steps of:

melting said members at a predetermined location to form a weld pool; and

disturbing the weld pool by introducing a disturbing member into the weld pool.

2. A method as claimed in claim 1, wherein the step of melting the members to form the weld pool is achieved by a using a plasma arc torch.

3. A method as claimed in claim 1 or claim 2, and including the step of clamping the overlapping members prior to forming the weld pool.

4. A method as claimed in any preceding claim, wherein the disturbing member is consumable.

5. A method as claimed in claim 4, wherein the disturbing member has a composition the same or similar to that of the metal forming the two or more members.

6. A method as claimed in any preceding claim, wherein the step of disturbing the weld pool comprises the steps of advancing the disturbing member into the weld pool at a predetermined rate and to a predetermined depth, and then withdrawing the disturbing member at a predetermined rate.

7. A method as claimed in claim 6, and including the intermediate step of holding the disturbing member in the weld pool for a predetermined time.

8. A method as claimed in claim 6 or claim 7, wherein the speed of advance and withdrawal of the disturbing member is variable.

9. A method as claimed in claim 8, wherein, the speed of withdrawal is equal to or faster than the speed of advance.

10. A method as claimed in any of claims 1 to 3, wherein the disturbing member is non-consumable.

11. A method as claimed in claim 10, wherein the disturbing member is made from a material which is not wetted by the molten metal of the weld pool.

12. A method as claimed in claim 10 or 11, wherein the step of disturbing the weld pool comprises the steps of advancing the disturbing member into the weld pool at a predetermined rate and to a predetermined depth, and then withdrawing the disturbing member.

13. A method as claimed in claim 12, and including the intermediate step of holding the disturbing member in the weld pool for a predetermined time.

14. A method as claimed in any preceding claim, wherein the movement of the disturbing member is at a relatively shallow angle to the plane of the weld.

15. A method as claimed in claim 14, wherein the angle is above 30°.

16. A method as claimed in claim 14 or claim 15, wherein the angle is up to 45°.

17. A method as claimed in any preceding claim, wherein the disturbing member is introduced into the weld pool to one side thereof to promote a stirring effect.

18. A method as claimed in claim 17, wherein two or more disturbing members are provided to promote such stirring.

19. A method as claimed in any preceding claim, the method including disturbance of the weld pool by a welding gas.

20. A method as claimed in claim 19 when dependant upon claim 2, the method including disturbance of the weld pool by the action of a shielding gas.

21. A method as claimed in claim 19 when dependent upon claim 2, or claim 20, the method including disturbance of the weld pool by the action of a plasma gas.

22. A method as claimed in any of claims 19 to 21, wherein the gas is caused to impinge on the weld pool at an angle and in a manner so as to promote swirling of the weld pool.

23. A method as claimed in any of claims 19 to 22, wherein the gas has a rotational component achieved by rifling in a gas delivery jet or nozzle.

24. A method as claimed in any preceding claim, wherein the weld pool is supported from beneath.

25. A method as claimed in claim 2, wherein the step of disturbing the weld pool includes disturbance by pulsing a welding current of a plasma arc torch.

26. A welding apparatus for welding two or more overlapping members having a tenacious surface oxide layer, the apparatus comprising a plasma arc torch operable to form a weld pool in a work piece, and weld pool disturbing means operable, in use, to disturb a weld pool formed by the plasma arc torch, the weld pool disturbing means comprising a disturbing member which is movable into the weld pool.

27. An apparatus as claimed in claim 26, and including a weld pool supporting member.

28. An apparatus as claimed in claim 26 or claim 27, wherein the disturbing member is consumable

29. An apparatus as claimed in claim 28 wherein the disturbing member comprises a wire or filament having a composition the same or similar to that of the workpiece.

30. An apparatus as claimed in claim 29, wherein the wire or filament is movable by a feed mechanism.

31. An apparatus as claimed in claim 30, wherein the feed mechanism is operable to move the wire or filament at one or more predetermined feed rates relative to the weld pool, in use.

32. An apparatus as claimed in claim 30 or claim 31, wherein the feed mechanism includes guide means to guide the wire or filament to a predetermined location in the weld pool.

33. An apparatus as claimed in claim 26 or claim 27, wherein the disturbing member is non-consumable.

34. An apparatus as claimed in claim 33 wherein the disturbing member comprises a lance or like implement.

35. An apparatus as claimed in claim 34, wherein the disturbing member is made from a material which is not wetted by the molten metal of the weld pool.

36. An apparatus as claimed in claim 27, wherein the support member comprises a support surface having a recess adapted to support the weld pool.

37. An apparatus as claimed in claim 36, wherein the support member is adapted to allow the recess to vent when the weld pool is formed.

38. An apparatus as claimed in claim 36 or 37, wherein the support surface is provided with one or more open channels extending from the recess.

39. An apparatus as claimed in any of claims 36 to 38, the support member comprising a body having an insert, the insert defining the support surface, wherein the insert is manufactured from a material having a lower thermal conductivity than the material of the body.

40. An apparatus as claimed in claim 39 wherein the insert is a ceramic material

41. An apparatus as claimed clim 39 wherein the insert is electrically conductive.

42. An apparatus as claimed in claim 41 wherein the insert is a graphite based material.

43. An apparatus as claimed in any of claims 36 to 42, wherein the support member is provided with a cooling system.

44. An apparatus as claimed in claim 43, wherein the support member has a substantially hollow interior through which coolant is circulatable.

45. An apparatus as claimed in any of claims 36 to 38, wherein the support member has a peripheral raised edge against which the work piece is received.

46. An apparatus as claimed in claim 45, wherein the edge is discontinuous.

47. An apparatus as claimed in any of claims 26 to 46, wherein the plasma arc torch and supporting member are movable relative to one another so as to enable the work piece to be clamped therebetween.

48. An apparatus as claimed in any of claims 26 to 47, wherein an electric welding current of the plasma torch is pulsable during welding in order to assist disturbance of the oxide layer

AMENDED CLAIMS

[received by the International Bureau on 27 December 2000 (27.12.00);
original claim 26 amended; remaining claims unchanged (5 pages)]

1. A method of welding two or more overlapping members having a tenacious surface oxide layer, the method comprising the steps of:

melting said members at a predetermined location to form a weld pool; and

disturbing the weld pool by introducing a disturbing member into the weld pool.

2. A method as claimed in claim 1, wherein the step of melting the members to form the weld pool is achieved by a using a plasma arc torch.

3. A method as claimed in claim 1 or claim 2, and including the step of clamping the overlapping members prior to forming the weld pool.

4. A method as claimed in any preceding claim, wherein the disturbing member is consumable.

5. A method as claimed in claim 4, wherein the disturbing member has a composition the same or similar to that of the metal forming the two or more members.

6. A method as claimed in any preceding claim, wherein the step of disturbing the weld pool comprises the steps of advancing the disturbing member into the weld pool at a predetermined rate and to a predetermined depth, and then withdrawing the disturbing member at a predetermined rate.

7. A method as claimed in claim 6, and including the intermediate step of holding the disturbing member in the weld pool for a predetermined time.

8. A method as claimed in claim 6 or claim 7, wherein the speed of advance and withdrawal of the disturbing member is variable.

9. A method as claimed in claim 8, wherein, the speed of withdrawal is equal to or faster than the speed of advance.

10. A method as claimed in any of claims 1 to 3, wherein the disturbing member is non-consumable.

11. A method as claimed in claim 10, wherein the disturbing member is made from a material which is not wetted by the molten metal of the weld pool.

12. A method as claimed in claim 10 or 11, wherein the step of disturbing the weld pool comprises the steps of advancing the disturbing member into the weld pool at a predetermined rate and to a predetermined depth, and then withdrawing the disturbing member.

13. A method as claimed in claim 12, and including the intermediate step of holding the disturbing member in the weld pool for a predetermined time.

14. A method as claimed in any preceding claim, wherein the movement of the disturbing member is at a relatively shallow angle to the plane of the weld.

15. A method as claimed in claim 14, wherein the angle is above 30°.

16. A method as claimed in claim 14 or claim 15, wherein the angle is up to 45°.

17. A method as claimed in any preceding claim, wherein the disturbing member is introduced into the weld pool to one side thereof to promote a stirring effect.

18. A method as claimed in claim 17, wherein two or more disturbing members are provided to promote such stirring.

19. A method as claimed in any preceding claim, the method including disturbance of the weld pool by a welding gas.

20. A method as claimed in claim 19 when dependant upon claim 2, the method including disturbance of the weld pool by the action of a shielding gas.

21. A method as claimed in claim 19 when dependent upon claim 2, or claim 20, the method including disturbance of the weld pool by the action of a plasma gas.

22. A method as claimed in any of claims 19 to 21, wherein the gas is caused to impinge on the weld pool at an angle and in a manner so as to promote swirling of the weld pool.

23. A method as claimed in any of claims 19 to 22, wherein the gas has a rotational component achieved by rifling in a gas delivery jet or nozzle.

24. A method as claimed in any preceding claim, wherein the weld pool is supported from beneath.

25. A method as claimed in claim 2, wherein the step of disturbing the weld pool includes disturbance by pulsing a welding current of a plasma arc torch.

26. A welding apparatus for welding two or more overlapping members having a tenacious surface oxide layer, the apparatus comprising a plasma arc torch operable to form a weld pool in a work piece, and weld pool disturbing means operable, in use, to disturb a weld pool formed by the plasma arc torch, and thereby enable mixing of the weld pool to break down the surface oxide layer present therein, the weld pool disturbing means comprising a disturbing member which is movable into the weld pool.

27. An apparatus as claimed in claim 26, and including a weld pool supporting member.

28. An apparatus as claimed in claim 26 or claim 27, wherein the disturbing member is consumable

29. An apparatus as claimed in claim 28 wherein the disturbing member comprises a wire or filament having a composition the same or similar to that of the workpiece.

30. An apparatus as claimed in claim 29, wherein the wire or filament is movable by a feed mechanism.

31. An apparatus as claimed in claim 30, wherein the feed mechanism is operable to move the wire or filament at one or more predetermined feed rates relative to the weld pool, in use.

32. An apparatus as claimed in claim 30 or claim 31, wherein the feed mechanism includes guide means to guide the wire or filament to a predetermined location in the weld pool.

33. An apparatus as claimed in claim 26 or claim 27, wherein the disturbing member is non-consumable.

34. An apparatus as claimed in claim 33 wherein the disturbing member comprises a lance or like implement.

35. An apparatus as claimed in claim 34, wherein the disturbing member is made from a material which is not wetted by the molten metal of the weld pool.

36. An apparatus as claimed in claim 27, wherein the support member comprises a support surface having a recess adapted to support the weld pool.

37. An apparatus as claimed in claim 36, wherein the support member is adapted to allow the recess to vent when the weld pool is formed.

38. An apparatus as claimed in claim 36 or 37, wherein the support surface is provided with one or more open channels extending from the recess.

39. An apparatus as claimed in any of claims 36 to 38, the support member comprising a body having an insert, the insert defining the support surface, wherein the insert is manufactured from a material having a lower thermal conductivity than the material of the body.

40. An apparatus as claimed in claim 39 wherein the insert is a ceramic material

41. An apparatus as claimed clim 39 wherein the insert is electrically conductive.

42. An apparatus as claimed in claim 41 wherein the insert is a graphite based material.

43. An apparatus as claimed in any of claims 36 to 42, wherein the support member is provided with a cooling system.

44. An apparatus as claimed in claim 43, wherein the support member has a substantially hollow interior through which coolant is circulatable.

45. An apparatus as claimed in any of claims 36 to 38, wherein the support member has a peripheral raised edge against which the work piece is received.

46. An apparatus as claimed in claim 45, wherein the edge is discontinuous.

47. An apparatus as claimed in any of claims 26 to 46, wherein the plasma arc torch and supporting member are movable relative to one another so as to enable the work piece to be clamped therebetween.

48. An apparatus as claimed in any of claims 26 to 47, wherein an electric welding current of the plasma torch is pulsable during welding in order to assist disturbance of the oxide layer

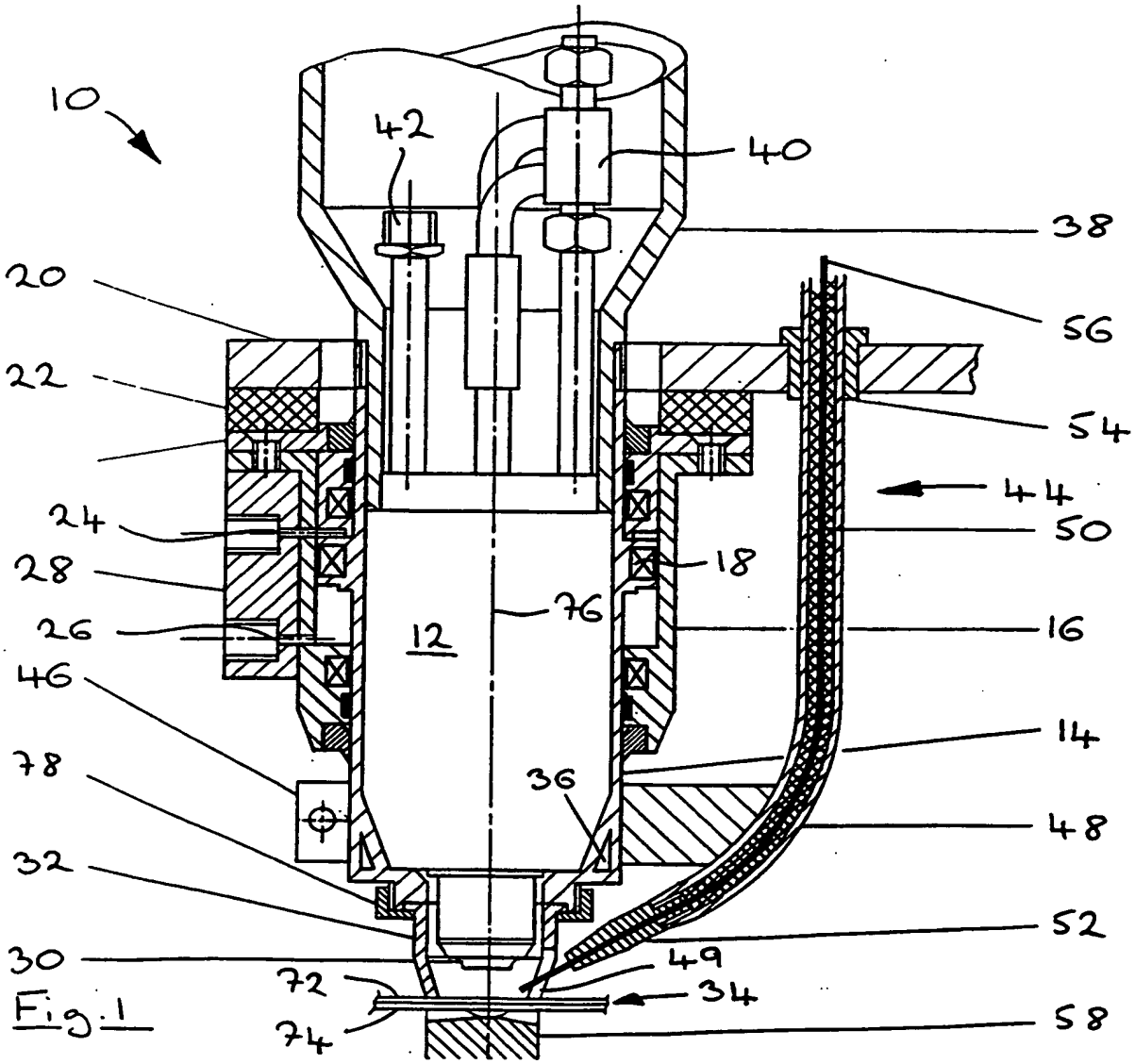
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Fig. 1

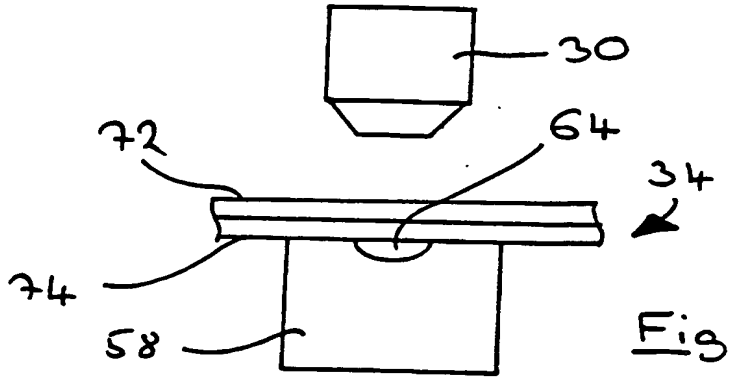

Fig. 2a

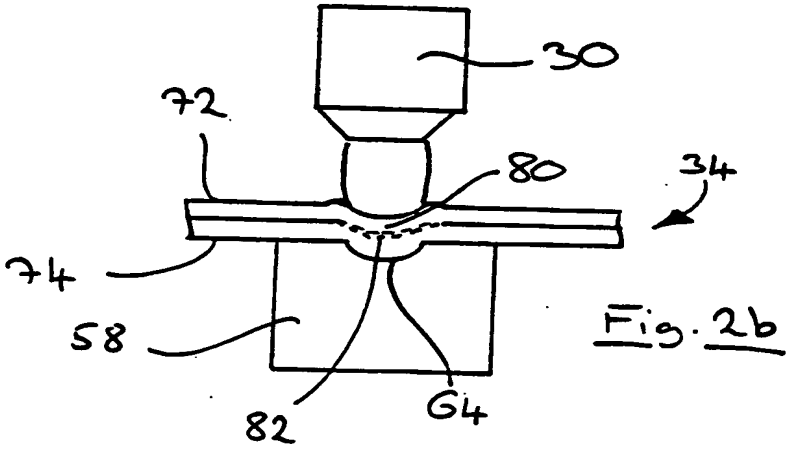

Fig. 2b

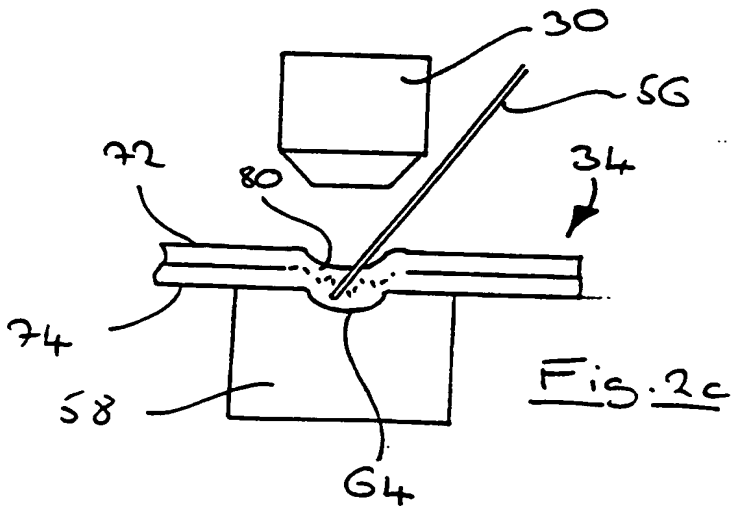

Fig. 2c

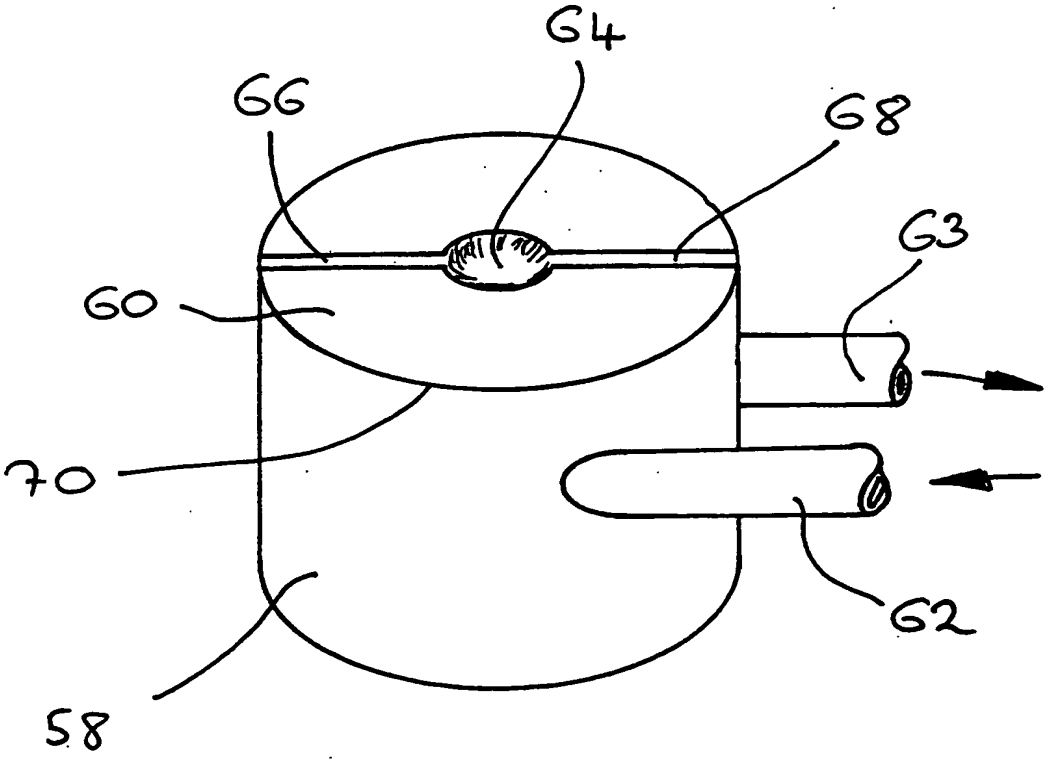

Fig. 3

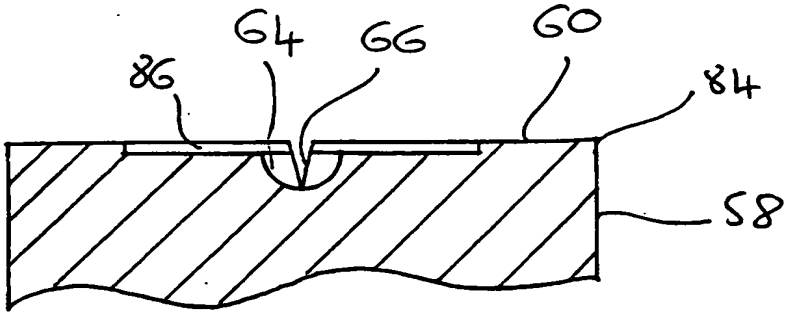

Fig. 4

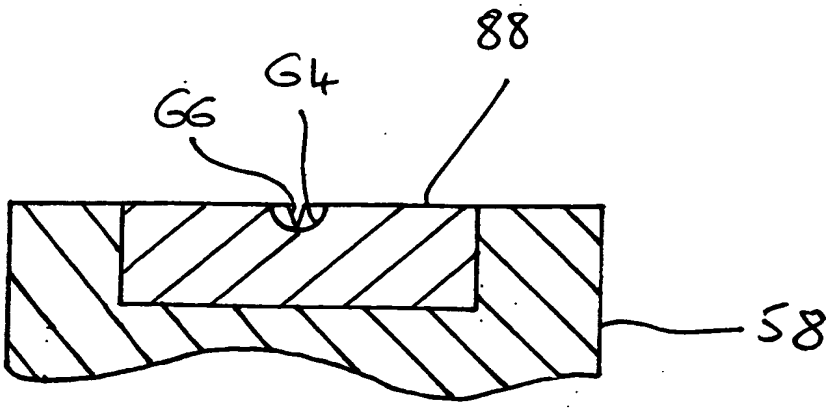

Fig. 5

INTERNATIONAL SEARCH REPORT

Int. Application No
PCT/GB 00/02920

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B23K9/23 B23K10/00 B23K37/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 B23K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
16 November 2000	24/11/2000

Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

Int. Application No
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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